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EFFECT OF VARIATION OF INTAKE DEPTHS ON WATER INJECTION TEMPERA--ETC(U)
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ABSTRACT

An investigation of the error in water temperatures introduced through use of the injection system is discussed. A series of tables and graphs show the magnitude of the temperature error owing to variations in intake depths.

Temperature gradients for the range of intake depths (10-30 feet) are less than 0.5°F at least 90 percent of the time. The average annual temperature error is 0.033°F although the absolute error varies between 0° and 0.3°F for the above gradient. The study concludes that the use of a thermistor probe in the intake system will yield sufficiently accurate measurements for the synoptic oceanographic net.

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EFFECT OF VARIATION OF INTAKE DEPTHS ON WATER INJECTION TEMPERATURES

I. INTRODUCTION

Sea surface temperature (SST) charts important to many aspects of oceanography are of particular interest to antisubmarine warfare (ASW) operations. In addition to their use for computing sonar ranges, these charts are also utilized in many cases for estimating subsurface thermal conditions. Since measurements of water temperature with depth are considerable more difficult to obtain than surface temperatures, the relationship between surface and subsurface temperatures is valuable. The ASW Environmental Prediction System (ASWEPS) currently under development at the Naval Oceanographic Office involves preparation of daily experimental synoptic SST charts for facsimile broadcast to Fleet units. These charts must be accurate and sufficiently detailed for operational utilization. Unfortunately, the reliability of the data from which these charts are prepared does not always ensure accurate analyses with the resolution desired.

Approximately 450 sea surface temperature reports are utilized in the preparation of a daily SST chart for the western North Atlantic Ocean. These observations, received via standard U.S. Weather Bureau teletype circuits, are reported by U.S. and foreign commercial and government ships at 6-hour intervals. With exception of occasional airborne radiation thermometer data and about 50 daily bathythermograph reports, these sea surface temperature

reports form the bulk of data used in SST charts and thus determine the reliability of the analyses. With few exceptions, the majority of the reports are based on thermometers mounted in ships' water intake systems. Although adequate for their intended use, these thermometers are generally inadequate for making accurate SST observations. Many studies concerning the accuracy of intake water temperatures have been made. Although each study concludes that better sensors are desirable, few agree on the magnitude of the average temperature error. Estimated average errors generally range between 1^{o} and $4^{o}F$. Further discussion concerning the accuracy of present water intake temperatures has been made by Saur (1963), Franceschini (1955), WMO Technical Note #2 (1954), and Kuhn (1963).

II. ERRORS IN WATER INTAKE TEMPERATURES

Water intake temperature errors generally fall into one of the following major categories:

1. Engine room heating,
2. Observer error,
3. Coding error,
4. Depth of water intake. p. 3

Reliable sea surface temperature charts can be prepared from injection temperatures after errors have been reduced to an acceptable limit. It is often difficult, however, to separate the error for a particular ship into quantitative contributions from each of the above categories, even though the relative

importance of each effect is known.

A. Although high <u>engine room temperatures</u> are often suggested as positively biasing intake temperature, this conclusion is not supported by facts. Computations reveal that for a 30°F differential between engine room ambient temperature and incoming water temperature, more than a 1,000-foot run of 8-inch intake pipe would be required to cause a water temperature increase of 0.1°F. This is assuming a flow of 2,000 gallons per minute, a normal figure while underway. The WMO (1954) study cites cases in which intake temperatures are lower than bucket temperatures, in spite of high engine room temperatures. The contribution of engine room heating to injection temperature error is thus considered insignificant.

B. <u>Observer errors</u> in reading the thermometer is undoubtedly the major cause of large temperature errors in injection readings. p.4

This error is not basically due to carelessness but is more a function of the inadequacy and inconvenient location of the injection thermometer. Intake thermometers mounted in inaccessible locations, such as behind machinery or other obstructions, render it physically impossible for the observer to obtain a correct position for accurate reading. In addition, the thermometers are often too gross, permitting estimates at only 2-degree intervals or, owing to age, have illegible scales. Such difficulties in making a reading result in poor temperature accuracy and lead to

fictitious values. The magnitude of these errors is unknown; however, it contributes the largest portion of the total intake temperature error and can be eliminated only by use of a better sensing system.

C. <u>Coding errors</u> are significant but offer the best possibility for correction. Gibson (1960), in a study of SST reports received via teletype and the same information as recorded on ships' weather logs, showed that 13 percent of the teletype reports were incorrectly coded. Thus, even though the original observation may be accurate, the transmitted observation may be erroneous. The majority of such errors become obvious through comparison of reported temperatures. Small errors, which may be significant, are difficult to determine. Errors due to coding can be reduced if the codes are simplified, e.g., direct SST reporting instead of present use of air-sea temperature difference and if the instructions for their use are made clear and concise. Review of coding errors through a quality control program also contributes to improved observations through renewed interest of the observers in the program.

D. Since many classes of ships report water temperatures and because each class has a different type of hull with a particular <u>depth of water intake</u>, errors occur in reported water temperatures because of the variation in sampling depths. p. 23 It is obvious that this error is large in the summer and small or nonexistent

during winter owing to the seasonal characteristics of the vertical thermal structure. The magnitude of the error is unknown but should be estimated prior to establishment of an improved sensor system based on location of the intake.

III. IMPROVEMENT OF SENSOR SYSTEMS

The importance of the last category arises from the ease of placing improved instrumentation in the intake system. Several other possibilities would eliminate use of the intake, but tests of such instrumentation (Kuhn, 1963) have shown that a thermistor probe in the intake system gives results as good as those achieved by other means. Such instrumentation also has the added advantages of ease of installation and relative freedom from maintenance. One possible method, for instance, would employ towed sensors which remain at a constant depth. Such instruments have either developed vibration problems leading to failure of the unit or have not maintained a constant depth. Hull-mounted sensors are more expensive to install, tend to foul easily, and are liable to total destruction by floating objects. Infrared temperature devices are accurate if they are sufficiently sophisticated; however, inexpensive models such as would be required for a large-scale installation program show considerable variations in temperature readings with slight changes in observing angle. Although buckets appear to be a simple, economical means of obtaining reliable data, they have several disadvantages. First, unless the observer is extremely careful, the bucket reading is modified by air

temperature and evaporative cooling. Second, bucket readings are difficult to make at night, during storms, or from larger ships. Consequently, observations may be missed. A partial problem will remain in all alternative systems, unless a dial readout is available on the bridge to reduce the reporting of water temperatures to a simple task without interfering with ship operations.

Discussions with representatives of the U.S. Coast Guard, U.S. Weather Bureau, and other interested parties indicate general agreement as to the superiority of the intake system for collecting data. On the basis of these discussions it is planned to utilize thermistor probes in intakes and a dial readout on the bridge for improving synoptic SST reports in the ASWEPS program. The bridge installation can be used with a continuous recorder; however, the recorder will generally be used only during transits of special regions. This installation will almost eliminate observer error and greatly improve reliability of SST reports.

IV. OBJECTIVE OF REPORT

The objective of this report is to investigate errors in water injection temperatures due to variation in sensing depths.

V. APPROACH TO PROBLEM

Injection temperature errors were evaluated with synoptic ship reports and bathythermograph observations received at the Oceanographic Office from the ASWEPS synoptic net through application of the following procedures.

1. Identification of the types of ships reporting to the synoptic net by reference to the synoptic ship weather reports.

2. From the ship types identified by step 1 a histogram was constructed to show the distribution of SST reports received from ships with various specified intake depths.

3. Next, by inspection of daily bathythermograph traces, the monthly and annual percent occurrences of various vertical water temperature gradients were ascertained.

4. Relate the two variables, distribution of intake depths and occurrence of vertical temperature gradients, to show the magnitude of the error introduced by utilizing a variable sensing depth.

VI. DISCUSSION

Each of the above steps is discussed separately below:

A. IDENTIFICATION OF TYPES OF SHIPS REPORTING TO THE SYNOPTIC NET

Ship weather reports for one day from each season were selected for the first step. Days selected were 15 August and 8 November 1962 and 1 February and 2 May 1963. A total of 705 reports were available from these days. Only U.S. ship reports were utilized, since installation of improved sensors is planned for only these ships.

Of the 705 reports evaluated, 66 percent were received from U.S. merchant ships; the remainder were reported equally by

U.S. Coast Guard and U.S. Navy ships as shown in table 1. Owing possibly to adverse weather, the lowest number of reports was made on 1 February. The large variation in U.S. Navy ship reports results from the scheduling of fleet exercises which places groups of ships at sea or in port. Regarding synoptic periods 33 percent of the reports were transmitted at 1800Z, 26 percent at 1200Z, 23 percent at 0000Z, and 18 percent at 0600Z.

TABLE 1. DISTRIBUTION OF SHIP REPORTS DURING SELECTED DAYS

Date	Merchant Ships	Navy Ships	Coast Guard Ships	Total
1 Feb 63	102	10	34	146
2 May 63	102	75	27	204
15 Aug 62	133	9	31	173
8 Nov 62	127	35	20	182
Total	464	129	112	705

When making weather reports, ships normally identify themselves by individual international call signs. Thus it is necessary to convert each call sign to a name before the intake depth can be determined, since ship names are needed to identify hull types and, subsequently, the intake depths. Identification was made by reference to the U.S. Coast Guard List of Merchant Ships, various Navy Identifier Lists, the Military Sea Transportation Service Ship Register, and Ships and Aircraft (1958); and a tabulation of full-load drafts was prepared for 626 of the 705 ship reports. The remainder could not be identified for a variety of reasons.

Since ship specifications do not state water intake depth, these depths were computed by relationship to the full-load draft.

Discussions were held with marine engineers and other cognizant personnel from the Bureau of Ships, U.S. Coast Guard, U.S. Weather Bureau, and Maritime Administration to establish the relationship between the full-load draft and intake depth for each hull type identified in the 626 reports.

B. DISTRIBUTION OF INTAKE DEPTHS

Figure 1 shows the distribution of intake depth for the ships filing the 626 weather reports. Intake depths varied from 10 to 32 feet with an average of 21 feet. The most frequent depth was 23 feet. Over 92 percent of the ships had intake depths within a range of 15 feet, and 65 percent were within a range of 5 or less feet. From figure 1 it is apparent that the water temperature error can be minimized by installing instrumentation on only those ships having intake depths close to 23 feet, since most intake depths fall in this category. Of course, this would mean that SST analyses would represent a depth of 23 feet.

The variation shown in figure 1 is greater than normal since the intake depths were computed for fully loaded ships; however, many of the ships are not usually fully loaded. The effect of this assumption is to centralize the distribution since, for a 50 percent load, the decrease in absolute draft is greater for larger ships than for smaller.

C. VERTICAL WATER TEMPERATURE GRADIENTS

The first step for estimating the vertical water temperature

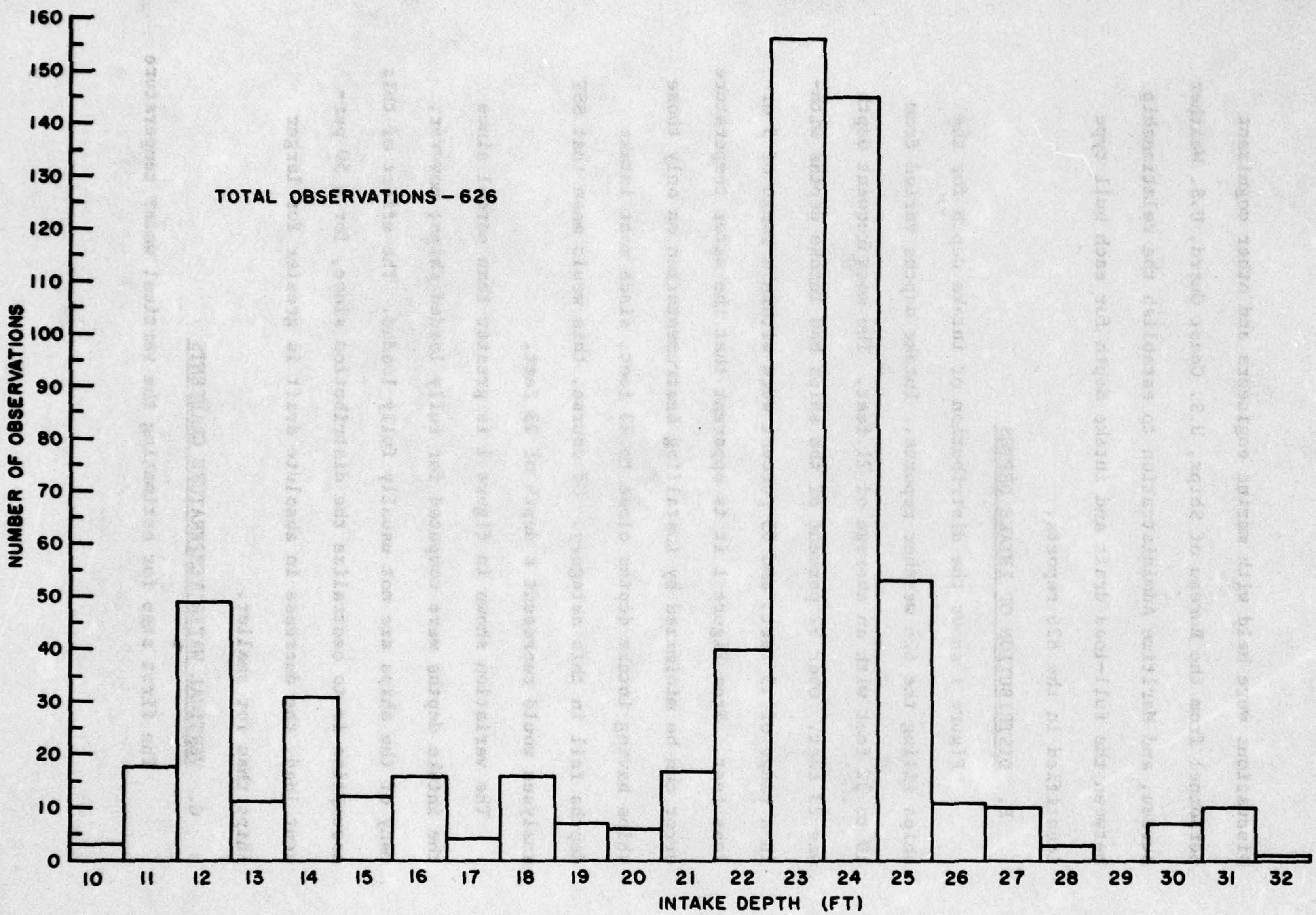

FIGURE I VARIATION IN DEPTH OF THE WATER INTAKE FOR TYPICAL SHIPS UTILIZED IN ASWEPS

gradients in time and space included typing of a number of water masses by temperature gradients and computation of the areal coverage of each water mass. Upon further consideration, however, this method appeared too subjective; therefore, the daily bathythermograph reports from ships of the synoptic net were utilized to obtain vertical temperature gradients. These bathythermographs were randomly located with the exception of picket ships and an ocean station vessel. To avoid areal bias only one report a day from each of these ships was utilized in the study. All remaining BT reports for the area shown in figure 2 were used.

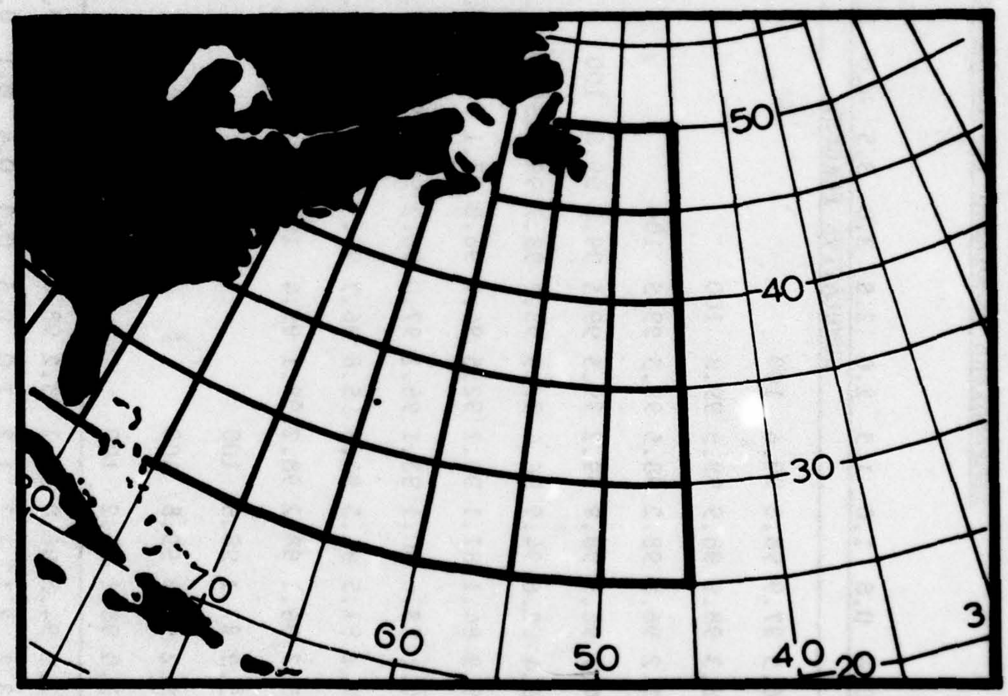

FIGURE 2 AREA FROM WHICH BT REPORTS WERE UTILIZED FOR COMPUTATION OF VERTICAL TEMPERATURE GRADIENTS

This area was selected because as the ASWEPS primary area of interest it is sufficiently large to include a variety of water masses and has the most complete coverage of bathythermograph reports.

TABLE 2 CUMULATIVE PERCENT OCCURRENCE OF VERTICAL TEMPERATURE GRADIENTS (10 to 30 ft.)

MONTH	N	0	0.2	0.4	0.6	0.8	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	>7.5	Gradient (^{o}F/20 ft.)
		CUMULATIVE PERCENT																			
JAN	405	69.4	91.9	95.6	96.5	97.9	98.6	99.6	100												
FEB	339	72.6	94.1	96.8	98.3	98.9	98.9	99.5	99.8	100											
MAR	292	66.1	92.8	95.2	95.2	96.9	98.2	98.5	99.5	99.5	100										
APR	335	54.3	84.2	92.3	94.7	96.5	98.9	99.2	99.5	99.5	99.8	99.8	100								
MAY	391	40.2	71.4	83.2	89.4	92.6	94.9	96.4	97.9	98.7	98.7	99.5	99.5	99.5	99.5	99.8	99.8	99.8	100		
JUNE	371	39.6	60.6	74.1	79.2	84.1	87.1	90.1	92.5	94.7	96.0	97.1	97.9	98.4	98.4	98.4	98.7	99.2	99.2	100	
JULY	338	41.7	66.0	77.5	84.1	88.6	90.1	93.1	96.1	97.0	98.2	98.5	98.5	99.1	99.1	99.7	99.8	99.8	100		
AUG	322	42.9	68.6	77.9	84.7	87.5	91.5	94.6	95.8	96.7	97.3	99.3	99.5	99.5	100						
SEPT	333	55.6	85.0	91.6	93.7	96.1	98.2	98.2	99.1	99.4	100										
OCT	337	64.1	89.9	92.9	95.9	97.1	98.6	100													
NOV	305	76.4	94.5	97.5	99.2	99.8	99.8	100													
DEC	271	74.1	94.8	97.0	97.0	98.1	99.2	100													
ANNUAL	4039	57.4	82.3	89.0	92.2	94.3	96.0	97.2	98.2	98.7	99.0	99.4	99.5	99.6	99.7	99.8	99.8	99.9	99.9	100	(Cumulative)
		57.4	24.9	6.7	3.2	2.1	1.7	1.2	1.0	0.5	0.3	0.4	0.1	0.1	0.1	0.1	0.05	0.05	0.05	0.05	(Absolute)

Temperature gradients at depths between 10 and 30 feet were extracted from the appropriate bathythermograms. A 30-foot depth was chosen instead of the maximum intake depth of 32 feet in order to simplify later calculations relating temperature gradients to intake depths. The majority of traces, including those with positive and negative gradients, were linear through the 20-foot layer under study. Gradients were tabulated in class intervals of 0.2°F.

Table 2 shows the results of these tabulations as cumulative percent occurrences of various temperature gradients. Only monthly cumulative values are shown, while both annual cumulative and annual individual category percents are given. Seasonal changes in thermal structure are evident from table 2, which was based on a total of 4,029 thermal traces. Note the predominance of isothermal temperature traces during winter (66 to 76%) and that the winter traces have vertical temperature gradients of 0.2°F or less per 20 feet more than 90 percent of the time. In December 74% of the traces were isothermal and 95 percent had gradients of 0.2 F or less per 20 feet. An increase in the occurrence of greater temperature gradient occurs toward summer: only 40 percent of the bathythermographs collected in June exhibited isothermal conditions. Isothermal conditions during the summer were generally restricted to the Gulf Stream; however,

mixed layers to 30 feet were found in colder waters on some occasions. In terms of the 90 percentile (table 2), 90 percent of the examined traces had vertical temperature gradients of 0.2°F or less during winter. During three transitional months (April, September, October), 90 percent of the traces had temperature gradients of 0.4°F or less; and from May through August 90 percent of the traces examined had gradients of 1.0°F or less. Although there is a high percent of isothermal or small negative gradients, these results are to be expected for two reasons: first, the study only considers conditions to 30 feet; and second, relatively little wind action is required to mix water to this depth.

Annual values of absolute and cumulative percent occurrences of temperature gradients show that 57.4 percent of the time the vertical temperature gradient between 10 and 30 feet is zero. It obviously follows that 57.4 percent of the time there will be no error in intake temperatures, regardless of intake depths. However, there are vertical temperature gradients of varying amounts during the remaining 42.6 percent of the time with the magnitude of the temperature errors depending upon the size of the ship. Temperature error is considered in this study to be the difference between temperature recorded at intake depth and temperature at some standard depth. The standard depth will not be the surface, since a more conservative temperature is obtained below the surface.

For example, 24.8 percent of the ships have 23-foot intake depths. If this depth is chosen as the "analysis depth," or the depth at which the synoptic SST analysis applies, then these ships will have no temperature error despite the vertical thermal gradient since the temperature values will not deviate from the analysis depth. The remainder of the ships will exhibit some temperature error, the magnitude of the error being a function of the deviation of a ship's intake from 23 feet and the extent of the vertical temperature gradient. The final step of the procedures outlined is portrayal of temperature errors resulting from various combinations of these two variables.

D. RELATION OF DISTRIBUTION OF VERTICAL TEMPERATURE GRADIENTS TO DISTRIBUTION OF INTAKE DEPTHS TO ILLUSTRATE TEMPERATURE ERRORS

From figure 1 and table 2 it is obvious that an infinite number of temperature errors are possible, depending on the particular ship type and temperature gradient considered. Table 2 shows no temperature error 57.4 percent of the time owing to isothermal conditions. Table 2 also shows that 82.3 percent of the time vertical thermal gradients are 0.2°F per 20 or less feet. Assuming that all of the ship types encounter this gradient during the year, sensor depths would vary from 10 to 32 feet (figure 1). It follows that the temperature error would vary from 0°F for ships with a 23-foot intake depth to a maximum of 0.13°F for the smallest ships or those having a 10-foot intake depth. If a larger vertical gradient is considered, the range and maximum possible value of

temperature error increase. Thus for a gradient of 3.0°F per 20 feet , which occurs 0.3 percent of the time according to table 2, the temperature error would vary from 0° to 1.95°F depending on ship type. If all the temperature gradients listed in table 2 and all intake depth shown in figure 1 are considered, temperature errors between 0° and 6.5°F are possible. The largest error, however, has very little chance of occurring, because the large gradient necessary to produce this error occurs only .05 percent of the time; and ships with maximum deviation of intake from 23 feet (which also contributes to large errors) represent only 0.5 percent of the ships studied. Thus, it is very improbable that the two extremes of gradient and intake depth would coincide to produce an error of 6.5°F.

Knowledge of the temperature error range is insufficient for deciding the importance of the temperature error. Three interpretations of the data given above in figure 1 and table 2 may suffice to illustrate the relative importance of the temperature error.

1. <u>AVERAGE TEMPERATURE ERRORS</u>

One form of presentation involves computation of average temperature errors for a given month or year. Since both the vertical temperature gradients and ship type are represented by distribution functions, the magnitude and percent occurrence of the various gradients and intake depths must be considered in computing average temperature errors.

The first step is determination of percent occurrence of ship types deviating a specified number of feet from the analysis depth of 23 feet. Table 3 gives both individual and cumulative percents for each class interval.

TABLE 3

DEVIATIONS OF SHIP INTAKE DEPTHS FROM ANALYSIS DEPTH (23 FEET)

Deviation (Ft.)	Percent of Ships In Interval	Cumulative Percent
0	24.8	24.8
1	29.6	54.4
2	11.2	65.6
3	2.8	68.4
4	2.7	71.1
5	3.1	74.2
6	0.6	74.8
7	3.7	78.5
8	3.5	82.0
9	5.2	87.2
10	1.8	89.0
11	7.6	96.6
12	2.9	99.5
13	0.5	100.0

In order to calculate average temperature errors, it is necessary to assume that each ship type represented in table 3 experiences the various vertical temperature gradients in accordance with its occurrence in table 2. That is, each ship during the year encounters gradients of 0.2°F per 20 feet 24.9 percent of the time, 1.0°F per 20 feet 1.7 percent of the time, etc. The average temperature error for each gradient in table 2 is then found by computing the temperature error for each ship

type separately and weighting these errors with the number of ships in each class interval in table 3. For example, when all ships steam through a gradient of 2.0°F per 20 feet (table 3), those with a 23-foot intake depth (24.8 percent) will have no error. Ships having 22- or 24-foot intake depths account for another 29 percent, but will have an error of one-twentieth of the gradient or 0.1°F. Similarly, ships with 5-foot deviation (18- or 28-foot intake depths) will have an error five times as large (0.5°F). By weighting the error for each intake depth with the percent of ships having that particular intake depth, an average temperature error of 0.33°F was found for a gradient of 2.0°F per 20 feet. Although 0.33°F was the average temperature error, it should be noted that absolute temperature errors of ships assumed to encounter a gradient of 2.0°F per 20 feet would range from zero to 1.3°F.

Once the average temperature error is found for a gradient of 2.0°F per 20 feet, the error for all gradients in table 2 can be determined through proportionality. That is, since the same distribution of ships (and thus intake depths) is applied to each gradient, the average temperature error for any particular gradient is found by multiplying 0.33°F by the ratio of the desired gradient and 2.0°F. Selected gradients and their associated average errors are shown in table 4.

TABLE 4

AVERAGE TEMPERATURE ERRORS FOR GIVEN VERTICAL TEMPERATURE GRADIENTS

Vertical Temperature Gradient (^{o}F/20 ft.)	Average Temperature Error (^{o}F)
0	0
0.4	0.066
0.8	0.132
2.0	0.330
5.0	0.825
7.0	1.155
10.0	1.650

The average monthly or annual error can be computed by weighting the temperature error for a given gradient with the percent occurrence of that gradient during the desired time period. For example, a gradient of 0.4^{o}F per 20 feet results in an average error of 0.066^{o}F (table 4) and occurs 6.7 percent (table 2) of the time during a year. The same average error would show up during 8.1 percent of April and 2.2 percent of December. By considering the percent occurrence of all the gradients during the year, an average annual temperature error of 0.033^{o}F was found. This value is small, of course, because of the high occurrence of small or zero gradients.

Figure 3 shows the average temperature errors for a winter, summer, and transitional month (September) plotted against the percent occurrences of gradients producing the errors. Thus the average error of 0.066^{o}F for the gradient of 0.4 F per 20 feet will occur during 3.5 percent of winter, 8.5 percent of

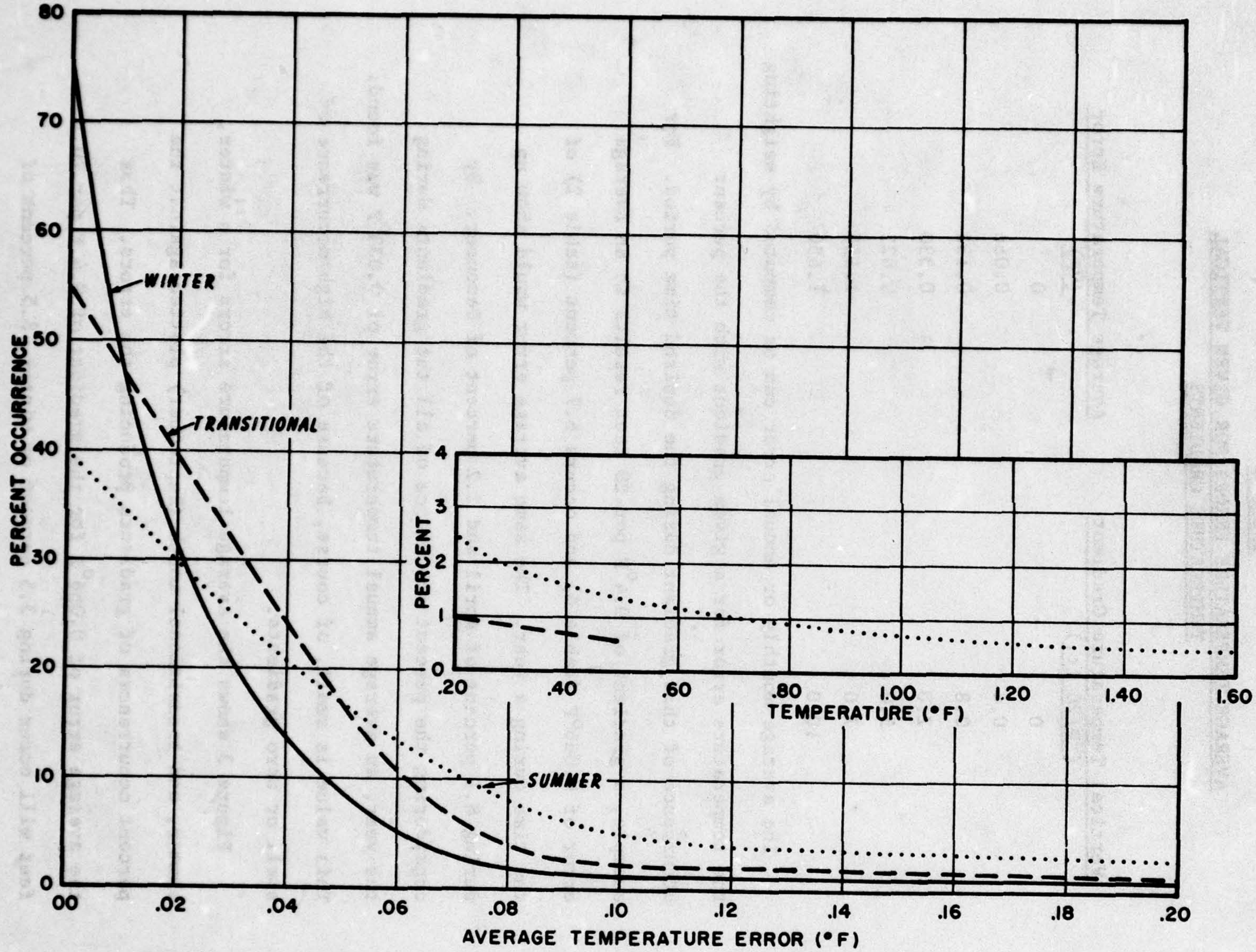

FIGURE 3 PERCENT OCCURRENCE OF AVERAGE TEMPERATURE ERRORS DURING WINTER, SUMMER, AND TRANSITIONAL MONTHS

transitional periods, and 11 percent of summer. As would be expected in winter, when small gradients predominate, the curve shows a high percent of small errors and large errors to be almost negligible. The summer curve is the only curve that shows errors larger than 0.60°F; however, these errors occur only a small percent of the time.

Small average temperature errors resulting from predominance of small gradients are misleading. To better illustrate the possible temperature errors from variations of intake depths, two other presentations of the data are given below.

2. <u>ABSOLUTE TEMPERATURE ERRORS FOR VARIOUS GRADIENTS</u>

During the year, it can be assumed that all ship types will encounter all of the various gradients. If only the ships having intake depths near 23 feet are considered, the errors possible in any gradient are relatively small, the magnitude being a function of the gradient. If all ships are considered, the possible errors increase as intake depths deviate from 23 feet. Figure 4 shows absolute temperature errors for various gradients as a function of ship types. This figure shows that 55 percent of the ships with intakes nearest 23 feet have a temperature error of less than 0.1°F when the gradient is 2.0°F per 20 feet. Eighty percent of the ships with intakes nearest 23 feet show an error equal to 0.8°F or less in a gradient of 2.0°F per 20 feet. Table 4 shows the average error for this gradient

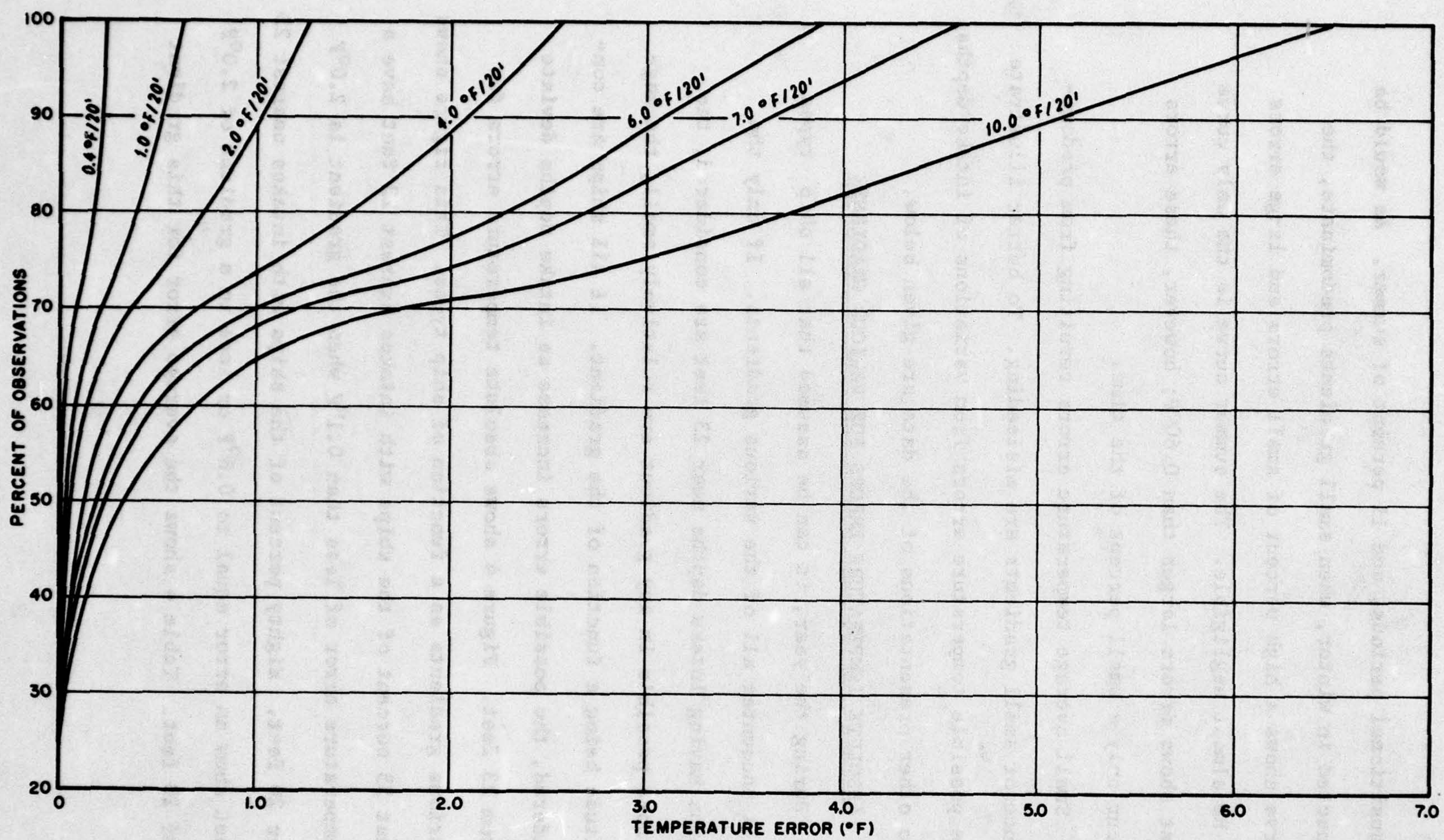

FIGURE 4 TEMPERATURE ERROR AS A FUNCTION OF TEMPERATURE GRADIENTS AND THE PERCENT OF SHIPS CONSIDERED

to be 0.33°F. Figure 4 shows that the error ranges from 0° to 1.3°F, depending upon the percentage of ships considered. Figure 4 is important in that it shows how small the range of error will be if installations are limited to ships having intakes near 23 feet. Although the largest error shown in figure 4 is 6.5°F, greater errors occur when gradients exceed 10°F per 20 feet; however, larger errors are infrequent and were not found in this study. Large temperature differences could also occur if two ships of extreme drafts report from the same location. Of course, one temperature would be low, the other high.

3. ABSOLUTE TEMPERATURE ERRORS FOR VARIOUS INTAKE DEPTHS

Absolute temperature error expected for intake depths between 10 and 29 feet at various gradients are shown in figure 5. An intake depth of 27 feet would have an expected error of 0.08°F or less 89 percent of the time, 0.4°F or less 98 percent of the time, and 2.0°F or less 100 percent of the time.

Figure 5 also shows for a given gradient, for example, 3°F per 20 feet, that the absolute temperature error is 0.3°F for ships with 21- or 23-foot intakes and 1.5°F for a 13-foot intake.

VII. CONCLUSIONS

By use of the tables and figures in this study, it is possible to determine temperature errors between 0° and 11.5°F. Thus,

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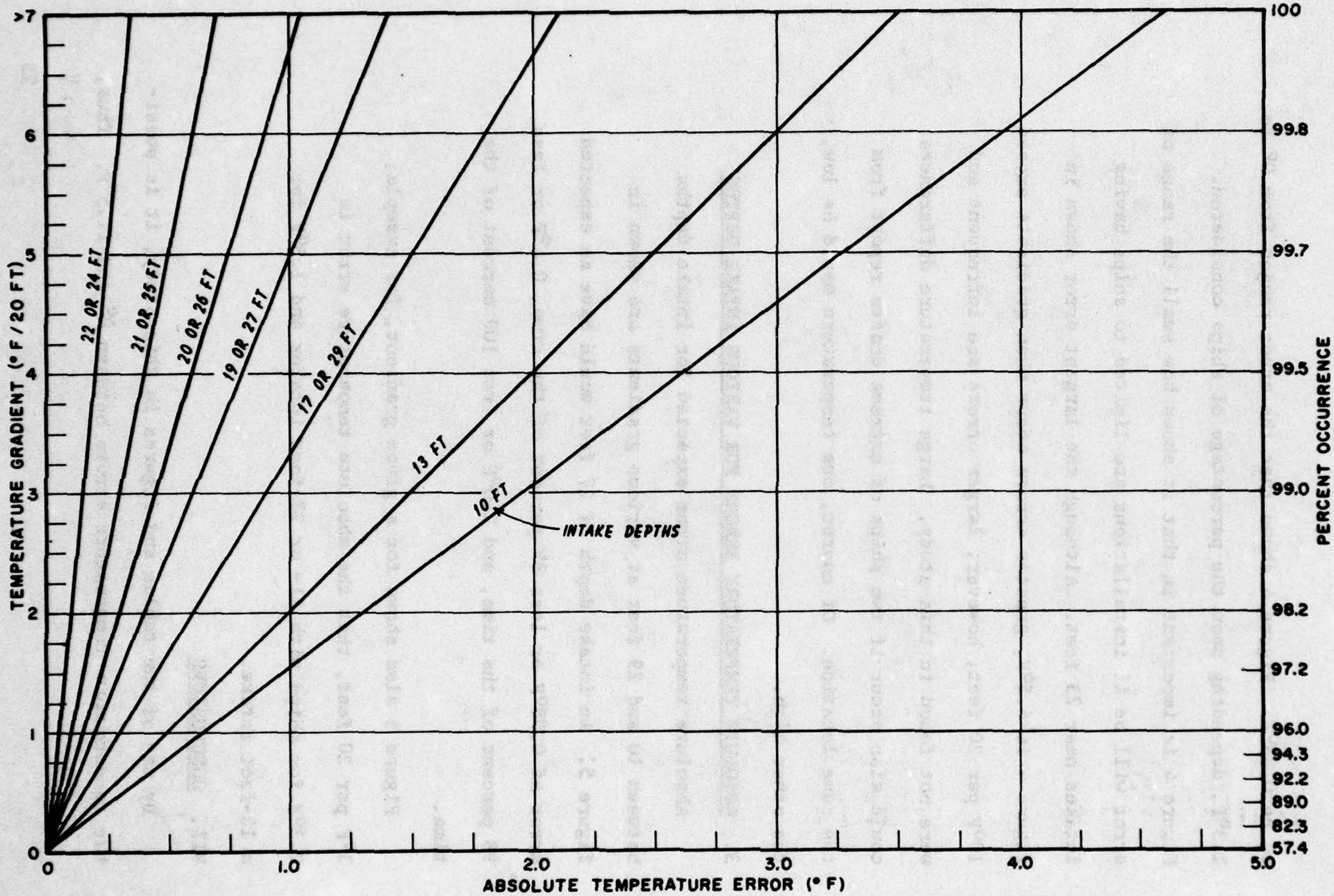

FIGURE 5 ABSOLUTE TEMPERATURE ERROR AS A FUNCTION OF TEMPERATURE GRADIENTS AND SHIP INTAKE DEPTHS

it is difficult to select any value as being representative of the magnitude of the temperature error resulting from variations in intake depths. The important points, however, are that the average annual temperature error is only 0.033°F, and ~~that~~ vertical gradients at the surface were less than 1.0°F per 20 feet 94 percent of the time. At this gradient, the average temperature error was only 0.165°F, and the absolute error for all intake depths ranged between zero and 0.6°F. This latter error could be halved by limiting installation to 75 percent of the ships. ~~(figure 4)~~.

This study concludes that it is feasible to utilize the intake system as a means of improving the accuracy of sea surface temperature observations for operational utilization. Despite occasional large temperature errors, it is clear that a large majority of errors will be negligible owing to combination of isothermal conditions and a peaked distribution of ship intake depths.

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